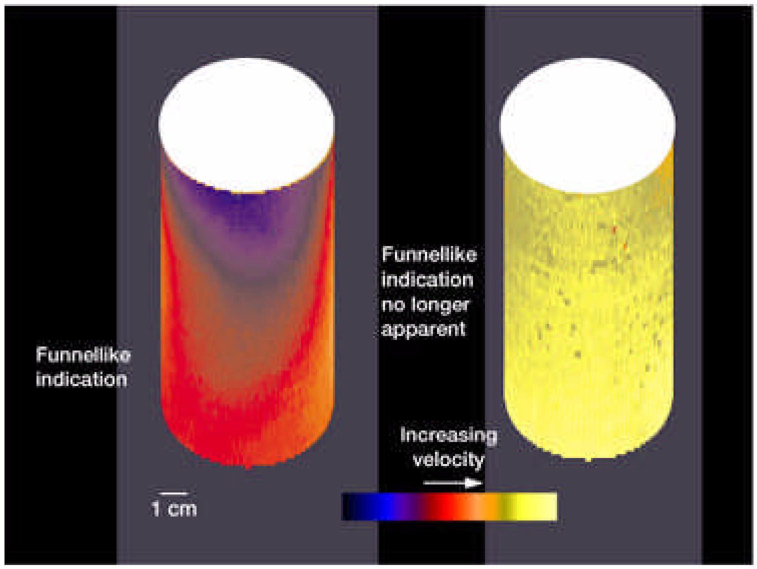
Novel Method Used to Inspect Curved and Tubular Structural Materials

At the NASA Lewis Research Center, a technique for the ultrasonic characterization of plates has been extended to tubes and to curved structures in general. In this technique, one performs measurements that yield a thickness-independent value of the local through-the-thickness speed of sound in a specimen. From such measurements at numerous locations across the specimen, one can construct a map of velocity as a function of location. The gradients of velocity indicated by such a map indicate local through-the-thickness-averaged microstructural parameters that affect the speed of sound. Such parameters include the pore volume fraction, mass density, fiber volume fraction (in the case of a composite material), and chemical composition. Apparatus was designed to apply the technique to tubular and other curved specimens.

The specimen was mounted on a horizontal turntable in a water tank, with its axis vertical and coincident with the turntable axis. A machined metal reflector plate narrow enough to fit within the inner diameter of the specimen was suspended vertically from above and positioned inside the specimen about 1 cm from the inner tube wall. A horizontally oriented ultrasonic transducer was positioned outside the specimen, facing the reflector plate. Then, pulse/echo measurements were taken in basically the same manner as for plate specimens. The transducer was translated vertically to obtain measurements at various axial positions (e.g., increments of 1 mm), and the turntable was rotated to obtain measurements at various azimuthal positions (e.g., increments of 1°).

The technique has been demonstrated in experiments on tubular specimens of mullite (silica/alumina), a polymer-matrix composite, a composite of SiC fibers in an SiC matrix, and a high-temperature structural grade of silicon nitride. Although the turntable, specimen, reflector plate, and transducer should be aligned as nearly perfectly as possible and the specimen should approximate a perfect round tube, it was observed that, in general, some misalignment and out of roundness can be tolerated. This is an advantage over peak-amplitude-based ultrasonic techniques in which measurements are altered drastically by refractive effects associated with out of roundness. The present technique made it possible to eliminate most of the effects of variations in tube-wall thicknesses upon velocity maps (through-the-thickness velocities as functions of axial and azimuthal positions). However, edge effects associated with discontinuous changes in thickness were not eliminated completely. In the case of the silicon nitride tube, differences between velocities at different locations were found to be correlated with differences between densities and pore volume fractions revealed by x-radiography and destructive metallographic analysis at those locations. The illustration shows the apparent (without thickness variation subtracted) and thickness-independent velocity images of the silicon nitride tube as decaled onto tubular models.



Apparent and thickness-independent velocity images of silicon nitride tube as decaled onto tubular models. Baseline orientation. Left: Apparent velocity image. Right: Thickness-independent velocity image.

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